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Original Article

Effect of backpack position on foot weight distribution of school-aged children

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Abstract. [Purpose] In the present study, we aimed to determine the effects of backpack position on foot weight distribution of standing school-aged children. [Subjects] Thirty school-aged children volunteered to participate in this study. [Methods] The subjects randomly performed four types of carrying a backpack: no backpack (condition-1), carrying a backpack at C7 (condition-2), carrying a backpack at 10 cm below C7 (condition-3), and carrying a backpack at 20 cm below C7 (condition-4). [Results] Statistically significant differences were noted in the anterior and posterior pressure values, and in the anterior-to-posterior ratio, among the four conditions ($p < 0.05$). Post-hoc analysis indicated that the pressure value of condition-4 was significantly lower in the anterior foot region and higher in the posterior foot region than in condition-2 and condition-3. In addition, the anterior-to-posterior ratio was lower in condition-4 than in condition-2 and condition-3. [Conclusion] These findings suggest that carrying a backpack in a higher position, with fastening of the shoulder strap, may be more favorable for normalizing the foot weight distribution.
Key words: Backpack position, Weight distribution, Children

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INTRODUCTION

Backpacks are indispensable, as people regularly use them for a long time to carry objects that are used daily[1)]. Therefore, avoidance of postural aberration, by practicing appropriate backpack usage, is vital. Recently, it has been suggested that the prolonged use of backpacks by school-aged children aggravates musculoskeletal conditions[2, 3)]. In particular, the increased prevalence of spinal deformities, such as scoliosis and kyphosis, and/or pain and discomfort including low back pain and shoulder pain, may be associated with backpack-carrying habits and the backpack weight[4–6)]. Occasionally, poor distribution of backpack weight and ineffective absorption of this load leads to postural changes, leading to musculoskeletal impairments[3)]. Hence, school-aged children should be educated and made aware of these concerns to protect their spinal health[7)].

To our knowledge, although the use of backpacks has a major influence on the spinal condition of school-aged children, the majority of studies have focused on the effects of backpack carrying on posture and movement during standing and walking of adults[8, 9)]. Due to this lack of research on juvenile subjects, it is challenging to establish a resource for educating children on the manner in which their backpacks should be correctly used. Hence, we sought to determine the effects of backpack use on children rather than review the outcomes of existing adult studies. Thus, we aimed to assess the effects of backpack position on the foot weight distribution of standing school-aged children.

SUBJECTS AND METHODS

Thirty healthy children (14 males, 16 females) volunteered to participate in this study. The mean age of the children was 8.43 ± 0.50 years, their mean height was 128.57 ± 6.06 cm, and their mean weight was 30.53 ± 4.17 kg. Only the subjects who fulfilled the following criteria were included in this study: no orthopedic, neurological, or cognitive impairments that could have influenced the study procedure or results; no discrepancy in leg length; and no regular daily exercise. All subjects signed a written consent form before study participation, and this study was approved by the Institutional Review Board of Cheongju University.

Foot weight distribution during standing was recorded using a force plate (FDM-s system, Zebris, Germany). This consists of a square plate (1.5 m × 1.5 m) containing 17,000 micro-sensors which detect foot pressure. A cable connects the force plate to the main unit, and a computer system with custom computer software for analyzing the measured data. The equipment evaluates the weight pressure distribution of the foot, and analyzes the load distribution of the anterior and posterior foot regions. We also calculated the anterior-to-posterior load ratio. Subjects were asked to stand still on the plate, with their feet shoulder length apart and their arms

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Table 1. Comparison of anterior and posterior pressure values and anterior-to-posterior ratios of the four backpack positions

	Condition-1	Condition-2	Condition-3	Condition-4
Anterior pressure values	39.45±10.96	42.04±12.16	40.64±13.51	37.50±11.18†‡
Posterior pressure values	60.56±10.96	57.96±12.16	59.36±13.51	62.51±11.18†‡
Anterior-to-Posterior ratio	0.72±0.39	0.82±0.48	0.80±0.54	0.65±0.31†‡

Condition-1: no backpack; Condition-2: carrying the backpack at C7; Condition-3: carrying the backpack at 10 cm below C7; and Condition-4: carrying the backpack at 20 cm below C7.
†Significant difference from condition-2.
‡Significant difference from condition-3.

at sides, while looking at a round target attached to wall located 2 m in front of them. After zero-point calibration, measurement was performed for 1 min and data were averaged over three trials separated by 1 min rest intervals.

Based on the study of Oh and Choi[10], four types of backpack (height: 34 cm, width: 25 cm, and depth: 13 cm) (BP-X031, PROSPECS, Republic of Korea) carrying conditions were studied. The backpack position was adjusted using the shoulder strap of the backpack: condition-1, no backpack; condition-2, carrying a backpack at C7; condition-3, carrying a backpack at 10 cm below C7; and condition-4, carrying a backpack at 20 cm below C7. The sequence of the four conditions was randomly determined to avoid an interaction effect of each condition. The randomization process involved blindly drawing a card from an envelope, containing 4 cards marked 1, 2, 3, or 4. We adjusted the weight of each backpack to 15% of the subject's bodyweight (average backpack weight of the subjects: 4.58±0.63), based on a suggestion made by Al-Khabbaz et al.[2], who investigated the effects of backpack weight load.

SPSS 12.0 was used to analyze all data. Data are presented as mean ± standard deviation (SD). One-way repeated analysis of variance was used for data analysis. Statistical significance was accepted for values of $p<0.05$. When statistical significance was identified, the differences in the pairwise comparison were examined using the post-hoc Bonferroni adjustment.

RESULTS

Table 1 displays the foot pressure results of each condition. Statistically significant differences were noted in the anterior and posterior pressure values, as well as the anterior-to-posterior ratio among the four conditions ($p < 0.05$). Post-hoc analysis indicated that the pressure values of condition-4 were significantly lower in the anterior foot region and higher in the posterior foot region than in condition-2 and condition-3. In addition, the anterior-to-posterior ratio was lower in condition-4 than in condition-2 and condition-3.

DISCUSSION

The excess weight load of a backpack causes asymmetry in the anterior and posterior load distribution, eliciting forward leaning of the upper trunk to adapt postural agitation and maintain postural balance[8]. Although the anterior-to-posterior pressure ratios did not significantly differ among the conditions, the ratios of condition-2 and condition-3 were greater than those of condition-1, implying that the weight load was greater in the anterior foot region and less in the posterior region. In condition-3, weight load appeared to be concentrated to a greater extent on the posterior, rather than the anterior foot region. A lower backpack position results in the increase of the moment arm generated by the upper trunk movement axis. Therefore, it may be difficult to maintain the appropriate pressure ratio on the anterior and posterior foot regions. Similar effects have been observed with increased backpack weight, indicating that carrying a backpack at a higher position, with fastening of the shoulder strap, may be better for normalizing foot weight distribution than other conditions. Our results are supported by the study performed by Gong et al[8].

Previous studies have reported that forward leaning of the upper trunk increases to a greater extent, when subjects carry a backpack in a lower position, with a longer shoulder strap[10, 11]. These studies indicated that the weight load is concentrated on the anterior foot region, which is inconsistent with our present study's findings. However, those studies examined walking of subjects, not standing of subjects, as in the present study. Given that additional load from a backpack can impede forward movement of the body during walking, forward trunk leaning may be an effective strategy for reducing energy consumption[10, 11]. Therefore, caution should be exercised when comparing our results with those of these previous studies, as their results require the understanding of the dynamic walking mechanism rather than that of static control that is behind the present study's findings.

We believe that carrying a backpack in the upper position may lead to safer use of the backpack, and may help prevent musculoskeletal discomfort in those who regularly use a backpack. Our findings suggest that adjusting the backpack position, by fastening the shoulder strap, is a useful strategy for the prevention of musculoskeletal problems in school-aged children.

This study had certain limitations, which should be addressed in further research. First, as the subjects of the present study included only school-aged children, the findings cannot be generalized to other age groups. Second, we did not record long-term follow-up data and the findings may not reflect long-term backpack use. Finally, the lack of other measures such as electromyography or kinematic analysis may be factors limiting the establishment of a more definite conclusion on the effects of backpack position.

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